oppoſed to each other, South to South; the Filings produced the ſame Appearance of Repulſion, as deſcribed in the fifth *Experiment*; then the Bars being brought ſo near as to touch each other at the ſame Poles, the Repulſion was inſtantly changed into Attraction.

III. *A Diſcourſe concerning the Uſefulneſs of* Thermometers *in Chemical Experiments; and concerning the Principles on which the* Thermometers *now in Uſe have been conſtructed; together with the Deſcription and Uſes of a* Metalline Thermometer, *newly invented by* Cromwell Mortimer *M. D.* Sec. R. S. *&c.*

Read May 8. 1735. *here printed with ſome Alterations.*

CHEMISTRY being the moſt extenſive Branch of Experimental Philoſophy, hath furniſh'd Mankind with the greateſt Number of curious and uſeful Diſcoveries; for not only the Art of ſeparating Metals from their Ores, of which Metals are form'd ſuch Variety of uſeful Inſtruments, but likewiſe Cookery, which is ſo much concern'd about the Food of Mankind during Health, and alſo Pharmacy, which furniſhes Medicines for the reſtoring Health when loſt, the Art of Dyeing, and many other uſeful Manufactures, all owe their Improvements to this Science; many of which have been light on unexpectedly by the Operator, while

he had ſomething elſe in View: but in many Caſes the Chemiſts complain, that, having once accidentally light on a curious Experiment, upon endeavouring to repeat it, they have never been able to make their Proceſs ſucceed exactly, as it did the firſt time, notwithſtanding that they made uſe of the ſame Materials, in the ſame Quantity, and conducted the Proceſs thro' exactly the ſame Operations. Where then muſt the Cauſe of the Miſcarriage lie? Surely in the Degree of Heat made uſe of in the two Experiments: For, in many common Operations, how uſual is it for a Preparation to be ſpoiled either by too little, or, moſt commonly, by too much Fire, too long or too ſhort a time applied! In order therefore to prevent theſe many Miſcarriages, I would adviſe the Chemiſt, in his Operations, to obſerve his Clock with as much Exactneſs as the Aſtronomer doth in his Obſervations; and in order to know to a Certainty the very Degrees of Heat he ever made uſe of in any Proceſs, that ſo he may be able to repeat and continue the ſame again in any Repetitions of the ſame Experiment, let him have his Laboratory furniſh'd with various Sorts of Thermometers, proportion'd to the Degree of Heat he intends to make uſe of. He will find theſe Inſtruments as uſeful to him in his Proceſſes, as they have proved to the curious Gardener in his Stoves, who by them is taught to keep his Plants in the ſame Degrees of Heat, as are natural to them in their reſpective Climates; which hath been ſet forth in Tables, after a very ingenious manner, by Mr.

* *Sheldrake* of *Norwich*. And beſides the enabling him to perform his Operations with more Exactneſs, theſe Inſtruments would ſave him a great deal of Fuel; for as Liquors, while boiling, are not capable of receiving a greater Degree of Heat, all Fuel which is uſed more than to keep them in that State is uſeleſs; and the like happens in many other Caſes.

Theſe Inſtruments would alſo be of great Service to Maltſters, Brewers, Diſtillers, and Vinegar-makers; for, by Thermometers placed in different Parts of the Heap of wetted Malt, the proper Heat for its ſprouting might be determined, and then regulated: The ſame for the Heat of the Kiln when the Malt is ſpread on it. By Thermometers the Brewer may aſcertain the Heat of the Water when he pours it upon the Malt, the Heat of the Wort when he ſets it to work, and the Heat while working: And in the like manner the Diſtiller and Vinegar-maker, in a Word, every Artificer, who employs Heat in his Buſineſs, may by theſe Inſtruments be certain of every Degree neceſſary in each Part of his Work.

Many Experiments ſhew, that all known Bodies, whether fluid or ſolid, increaſe their Bulk or rareſy by an Addition of Heat; and, on the contrary, contract or become more denſe by the Diminution of Heat, which is the Preſence of Cold: And theſe Alterations are always more or leſs ſenſible in proportion to the natural Rarity or Denſity of the Bodies. The

* Now Truſs-maker over againſt the End of *Suffolk-ſtreet* near *Charing-Croſs*, *London*, 1748.

The *Air* we live in, as it is the moſt rare and light Fluid, ſo are its Alterations the moſt ſenſible; and indeed I know of no Experiments which determine how far it is capable of being expanded by Heat, or condenſed by Cold; only we find that it will make its Way thro' any Fluid in which it lay dormant, when its elaſtic Property is rouzed by the Approach of ſuch an Heat as will make the Fluid boil. On the other hand, when compreſs'd by a Fluid ſo contracted by Cold, as to freeze, or become ſolid, its Elaſticity will only bear a certain Degree of Compreſſion, till the Force wherewith it endeavours to reſtore itſelf, exceeds the Force by which the Parts of the Solid, that confines it, adhere to each other, and ſo burſts its Priſon; as we often ſee during hard Froſts in Ice, and likewiſe Glaſs, and other hard Bodies, whoſe Parts cannot ſtretch.

Next to Air is *Alcohol*, or the higheſt rectified Spirit of Wine: This, Water, and all other Liquids, are capable of receiving no greater Degree of Heat than what makes them boil, as was firſt demonſtrated by Monſieur *Amontons*, a Member of the *Royal Academy des Sciences* at *Paris*; but that ingenious Inventor of the Quickſilver Thermometer Mr. *Fahrenheit* hath diſcover'd, that when the Barometer marks a greater Preſſure of the Atmoſphere, the ſame Liquor will receive 8 or 9 Degrees more of Heat than when the Barometer is at the loweſt. From hence the great Profeſſor *Boerhaave* gives the Hint, that, from nice Experiments being made of the different Degrees of Heat mark'd by a Thermometer in boiling Water compared with the different Heights of the Barometer, and Tables formed upon

upon them, a Thermometer applied to boiling Water might, at Sea, where the Motion of the Ship hinders Obſervations with the Barometer, ſerve to determine the Difference of the Gravity of the Atmoſphere. See his *Chemiſtry*, Tom. I. p. 171.

Theſe, and all other Liquids, by a certain determinate Degree of Cold peculiar to each ſort, loſe their Fluidity, and freeze, or become ſolid, but not in the ſame Order as by Heat they boil; for by Cold Oil or Water is ſooner frozen than Spirit of Wine, tho' Spirit of Wine will boil ſooner than Oil or Water. All ſolid Bodies likewiſe, as Minerals, Metals, and even Stones, will become fluid, or melt, at a certain Degree of Heat peculiar to each Species; and, when thoroughly melted, it is probable they are capable of receiving no higher Degree of Heat; and, on the Abſence of that Heat to a certain Degree, they all return to their natural ſolid State. Hence we may reaſonably conclude, that Solidity is the natural State of all Bodies; and that ſome are only accidentally fluid, becauſe their Conſtitution is ſuch as to melt by thoſe Degrees of Heat which our Atmoſphere is moſt commonly ſubject to. All ſolid Bodies are obſerved to contract themſelves into ſmaller Dimenſions by Cold, and gradually to expand themſelves at the Approach of Heat, till at laſt, being by Heat forc'd to the greateſt Degree of Expanſion, the Particles of which they are compoſed loſing their Coheſion, they become fluid; but no Experiments have yet been made, which determine whether Solids, expoſed to Cold beyond certain Degrees, will ceaſe to contract any more.

The learned Dr. *Muſchenbroek*, Prof. of Aſtronomy at *Utrecht*, and *F. R. S.* hath lately invented a very ingenious

ingenious Inſtrument, which he calls a *Pyrometer* and which Dr. *Deſaguliers* hath made ſome Improvements to * ; a full Deſcription of which he hath given in his *Courſe of Experimental Philoſophy*, *Vol.* I. *p.* 421. *&c.* By this Inſtrument the Elongation of Rods of ſeveral Sorts of Metals by the Approach of a certain Number of Flames of a Spirit-Lamp, and likewiſe their as ſudden Contraction, on the extinguiſhing one or more of thoſe Flames, is render'd ſenſible to the Eye: Which ſufficiently evidences the Matter of Fact, and puts it beyond all Doubt.

From the above-mention'd Property of Bodies contracting and expanding in Cold and Heat, have all Thermometers been conſtructed, that have ever been made uſe of in order to obſerve and compare the different Degrees of Heat, either in our Atmoſphere, or in other Bodies. The moſt ſimple and moſt ſenſible of any is that aëreal Thermometer deſcribed by the great Mr. *Boyle*, in his New Experiments and Obſervations touching Cold, *Lond.* 1683. *4to. p.* 39. It conſiſts of a glaſs Bubble, with a very ſlender Stem not bigger than a Raven's Quill. The Bubble is left full of Air, and a few Drops of Water being convey'd into the Stem in an erect Poſition, will there remain ſuſpended to a certain Height; but, by the leaſt Addition of Heat, the Air in the Bubble expanding will puſh the Water up higher

* This Inſtrument hath ſince been greatly improved by that ingenious Watch-maker Mr. *John Ellicot*, *F. R. S.* See *Phil. Tranſ.* N°. 443.

higher; or, by the Approach of Cold, the Air contracting, the Water will fall lower in the Stem. This Inſtrument may be of Uſe in ſmall Degrees of Heat, and in Cold, till the Water begins to freeze, when it becomes uſeleſs.

The next in Order of Senſibility is that firſt invented by *Cornelius Drebbelius* of *Alcmar*, and improved by *Boerhaave*. (See his *Chemiſtry*, Tom. I. p. 152, & 153.) It conſiſts of an hollow glaſs *Lens* joined to a Stem of a larger Size than in the preceding, and a Baſon into which the End of the Stem is inverted. The Air in the *Lens* muſt be ſo much rarefied, that the Stem being inverted into a tinged Liquor in the Baſon, the Liquor will riſe up ſome way in the Stem; then, by the Application of Heat to the *Lens*, the Liquor in the Stem will be puſh'd down, and by Cold the Liquor will riſe up. This Inſtrument will give Notice of the ſmalleſt Changes in the Air; but it cannot be immerſed into any Liquid for chemical Experiments, unleſs the Stem were made much longer, and bent down in Form of a Syphon: But even then it would be very unhandy, and, like the preceding, it would never ſerve for any Degree below what would freeze the Liquor made uſe of, nor for any above what would force out the confin'd Air through the Liquor in the Baſon. Beſides, both theſe Inſtruments, being ſubject to the Preſſure of the Atmoſphere, are not proper, without comparing the Barometer at the ſame time, to determine the Degrees of Heat at a great Diſtance of Time between each Experiment.

The

The moſt uſual Sort of Thermometers is that deſcribed in the Account of the Experiments by the *Academy* of *Cemento*; which being the common ones, made of Spirit of Wine ting'd, it is needleſs to deſcribe. The Bounds of the Degrees of Heat which theſe will meaſure, and which is commonly called the Range of the Inſtrument, are from the Degree which freezes Spirit of Wine, up to that which makes it boil. The Spirit-Thermometers, commonly made here in *London*, are ſo graduated, that when the Spirit is rarefied to the Degree that the moſt ſultry Sunſhine commonly known in our Climate of $51°\frac{1}{2}$ N. Lat. can raiſe it, there is placed the Mark 0. or Degree of no Cold. Some few are mark'd 10 or 20 above this, if they are deſign'd to be uſed in hotter Climates; but all are graduated downwards from this: So that the 45°. is the Point of temperate, and 65°. is the Point of freezing, and 100°. is plac'd juſt above the Ball. But the moſt accurate Spirit-Thermometers are thoſe lately made by the ingenious Mr. *Reaumur*, Member of the *Royal Academy* of *Sciences* at *Paris*; he hath taken a great deal of Pains, and uſed great Exactneſs, in fixing the certain Points of freezing of Water, of temperate Air, and boiling Water. He determines the freezing Point, by leaving his Thermometer a conſiderable time in Water, into which is put a good deal of Ice, at a time when the Water would not freeze of itſelf; and this he marks 0. or the Degree of no Heat; and his Scale is mark'd with Numbers running downwards from 0. meaſuring the Degrees of Cold, and upwards meaſuring the Degrees of Heat: At $10\frac{1}{7}$ upwards he marks

the Point of Temperate, which he determines by placing his Inſtrument in a ſubterranean Cavern, which is neither affected by Froſt nor Sunſhine, but is obſerved to keep an equable Temperature all the Year round; ſuch as deep Cellars and Wine-Vaults commonly do. In boiling Water he finds that his Thermometer riſes to his 80th Diviſion,* or 80 Degrees, which are formed by dividing the Spirit when condenſed to the freezing Point, into 1000 equal Parts; ſo that, with the Heat which makes Water boil, the Spirit is expanded only $\frac{80}{1000}$, more than with the Cold which freezes Water.

Theſe Spirit-Thermometers are of Uſe in Experiments where ſomewhat greater Cold than the freezing of Water is required; but they can never be of Uſe in any Degrees of Heat beyond the boiling of the Spirit itſelf; becauſe it then becomes volatile, or riſes up in Steam, and not only expands no more, but likewiſe the Quantity is diminiſhed by the Particles which fly up from the Surface of the Liquor, and are ſuſpended in the Top of the Tube.

Many have filled their Thermometers with various Sorts of Oils†: Theſe indeed will meaſure many Degrees above the boiling of Water, till they boil themſelves; and then they have the ſame Defect as the Spirit

* But, with Submiſſion to ſo great a Man, I cannot apprehend that his Thermometers, when the Spirits are raiſed up to 80 do mark any greater Degree of Heat than their own ſpecific boiling Heat, which, if they are *Alcohol*, or the moſt rectified Spirits, anſwer to 174. of *Fahrenheit*'s Scale; if of the Strength of common Brandy to 190. † See Dr. *Martin*'s Eſſays *Med. & Philoſ.* p. 225.

Spirit ones juſt mention'd, which is the Liquor loſing of its Bulk by Evaporation; and they congeal much ſooner than Water, and ſo are uſeleſs in meaſuring any Degrees of Cold.

The moſt uſeful Inſtruments, as they comprehend the largeſt Range, are the Mercurial Thermometers, which were brought into Uſe by that ingenious Artificer *Fahrenheit*, *F. R. S.* (See *Phil. Tranſ.* N°. 381.): But, to do Juſtice to a moſt worthy Member of the *Royal Society*, namely, Dr. *Halley*, he firſt gave the Hint, and even propoſed the making Thermometers of Quickſilver long before *Fahrenheit's* Time (See *Phil. Tranſ.* N°. 197. p. 652.). However, *Fahrenheit* deſerves Thanks from the World for having brought theſe Inſtruments into Uſe, becauſe they will meaſure the greateſt Degrees of Cold yet known; for no Cold hitherto obſerved hath been able to freeze or render *Mercury* ſolid: And in meaſuring Heat, they go far beyond boiling Water, even beyond the melting of Tin or Lead. *Fahrenheit* begins his Scale from 0. the Point to which the *Mercury* hath been obſerved to fall by the greateſt Cold in *Yſland*; and computes, that the *Mercury* then * occupies 11124 Parts. This is his Point of no Heat. Then reckoning upwards from this, he finds that when the *Mercury* is rarefied only 32 Parts or Degrees more, common Water juſt begins to freeze: In a temperate Air it will riſe to about 60. The moſt ſultry Sunſhine ſeldom raiſes it to 90; the Heat of an animal Body to 96; the boiling of *Alcohol* to 174; the boiling of

* See *Boerh. Chem.* Tom. I. *p.* 174.

of Water to 212; and before the *Mercury* itſelf boils, it will riſe to 600.

I cannot here forbear giving an Abſtract of a very curious and ſurpriſing Experiment of *Fahrenheit*'s, concerning the artificial Production of Cold, as it is related by *Boerhaave* in his *Chemiſtry*, Tom. I. p. 164. *Fahrenheit* had a *Mercurial* Thermometer made with ſo long a Stem, that he could carry down the Scale 76 Parts or Degrees below 0. With this Inſtrument he found, that Cold might be produced by gradually pouring Spirit of Nitre upon powder'd Ice, till the *Mercury* would ſubſide to 40° below 0. that is 72°* lower than the Cold which freezes common Water. *Boerhaave*, in his *Chemiſtry*, Tom. I. p. 161. mentions a very pretty Way of determining the freezing Point: He adviſes to hang the Thermometer free in the open Air, not againſt any Wall or Building; and near it you muſt hang a Piece of very fine Linen or Muſlin juſt dipp'd in clean Water: When this begins to grow ſtiff, you will find the *Mercury* ſtand at about the 33d Degree; and it will alſo ſtand at the ſame Height when an hoar Froſt appears upon the Ground; which he looks upon as a certain Sign of the Beginning of freezing.

Having thus given an Account of the ſeveral Sorts of Thermometers hitherto uſed, and what Degrees of Heat they are proper to meaſure, we find none of them capable of meaſuring the greater Degrees of Heat, which are the moſt commonly made uſe of

* But what is this to the marvellous natural Cold of *Siberia*, 120°. below 0? See the Preface to *Gmelin*'s Flora Siberica. *Petrop.* 1747. 4to.

of by the Chemiſts in many of their Operations. Beſides, all the above Inſtruments, being made of Glaſs, are eaſily broken by Accidents, and as liable to crack of themſelves, by being taken out of a great Heat, and too ſuddenly expoſed to Cold. I therefore conſider'd whether the above-mention'd Property of Solids, and eſpecially of Metals contracting with Cold, and expanding with Heat, might not be applied to the Conſtruction of an Inſtrument capable of meaſuring all Degrees even of the greateſt Cold, as well as the greateſt Heat, to the melting Copper or Iron, which require more Heat than any other Metals to melt them. Altho' the Alterations in Metals are but ſmall, in reſpect of thoſe in Spirits, or even *Mercury*, yet it being found, that Iron, *e. g.* becomes $\frac{1}{00}$ longer * when red-hot, than when of its natural Temperature; and Dr. *Derham*, in his laſt Paper read before the *Royal Society* concerning the Vibration of *Pendulums*, ſays, that a Rod $39.\frac{126}{1000}$ Inches long, becomes $\frac{1}{10}$ Inch longer than its natural Dimenſions in temperate Air, by being expoſed to Heat equal to that of an human Body; $\frac{2}{100}$ Inch longer in hot Sunſhine; that it was $\frac{2}{10}$ or $\frac{1}{5}$ Inch longer than its natural State, by being heated in a flaming Heat; that it became $\frac{7}{100}$ ſhorter than its natural Length by being quenched in cold Water; and ſtill $\frac{3}{100}$ ſhorter, by being put into a Mixture of Salt and Snow. From which Experiments one may conclude, that from *Fahrenheit's* Cold of 40 below 0. to the greateſt Heat Iron can bear without melting, a Rod of three Feet long will have about $\frac{1}{4}$ Inch Increaſe; which Increaſe of Length will be Range enough

* Vide *Sturm. Coll.*

enough to make all the intermediate Degrees obſervable upon an Inſtrument.

Suppoſe in *Fig.* 1. TAB. II. *AB* a Rod of Iron at its natural Length by the Heat of the Atmoſphere, placed upright upon one End; upon the Point of that reſts a Bar *CD* moveable on an Axis at *a*; and that, by making a Fire about the End *B* of the Rod, till it is juſt ready to melt, the Rod will increaſe in Length *Ab*, and conſequently puſh the Bar into the Situation *cd*. Now it is obvious to any one who underſtands ever ſo little of Mechanics, that tho' the Elongation of the Rod *Ab* be even ſcarce perceptible to the Eye, yet if upon the Bar *CD* the Diſtance *aA* from the Axis to the Place where the Rod *BA* puſhes againſt it be very ſmall, and the other Part of the Bar *aD* very long, the Arch *Dd* may be increaſed at Pleaſure, ſo as to bear to be divided into any Number of Diviſions that ſhall be found neceſſary: For the Arch *Dd* will always be to the Arch *Cc* in the ſame Proportion as the Diſtance *Da* is to *aC*; and likewiſe the Chords of theſe Arches *Dd* and *Ab* will be in the ſame Proportion; ♈, ♌, is the Situation of the Lever on the Level; and if it be found inconvenient to make the Arm *aD* ſo long, as to make very minute Alterations in the Length of the Rod *AB* eaſily obſervable, this Inconveniency may be readily removed by having a ſecond Bar *EF*, turning on the Axis *g*, whoſe Arm *gE* bearing up againſt the Extremity *D* of the firſt Bar or Lever, will riſe with it, or be preſs'd down by it; and the other Arm *gF* being lengthen'd at Pleaſure, the Arch *Ff* will be as large as you find convenient; or even a third and fourth Lever may be added.

When

When I firſt deſigned to have an Inſtrument conſtructed anſwering to the foregoing Principles of *Fig.* 1. I drew a Figure of it, wherein I propoſed the Lever *AD* to have terminated in two Arches of Circles made out of one Piece of Braſs; the ſmaller Arch formed on the Radius *aA* to be loaded with a Quantity of Metal ſufficient to overcome all the Friction of the ſeveral Parts, ſo as to preſs down with a conſiderable Weight, and always to reſt upon the Point *A* of the upright Rod *AB*; at *a* the Axis, on which they were to turn; and the larger Arch form'd on the Radius *aD*, was propoſed to be a Sextant, the outward Edge of which was to be toothed, which Teeth were to play into the Teeth of a ſmall braſs Wheel carrying a ſteel *Index* like the Minute-hand of a Clock, which ſmall Wheel with the Hand was to make one Revolution nearly by the utmoſt Riſe and Fall of the Sextant at *D*; or, inſtead of Teeth, I propoſed a Piece of a Watch-Chain to be faſten'd to the upper Limb of the Sextant, and ſo to be brought downwards, and paſſing nearly round the ſmall Wheel in one Groove, to be faſten'd to it: In another Groove in this ſmall Wheel was another Piece of Watch-Chain to be faſten'd, which, being paſſed contrarywiſe round the ſaid Wheel, was to have a Weight hung to it that would be a Counterpoiſe to the Sextant; but, upon conſulting my two ingenious Friends Mr. *Geo. Graham* and Mr. *John Ellicot* two worthy Members of this *Society*, they each of them perſuaded me to lay aſide that more complexed Conſtruction, and to have the Inſtrument made in the plain and ſimple manner in which Mr. *Jackſon*

Jackſon executed it for me in the Year 1736. as is repreſented in *Fig.* 2 and 3. TAB. II.

The Deſcription of the Inſtrument.

Fig. 2. *AB* a round Rod of Steel or Braſs a Quarter of an Inch thick, and 3 Feet 1 Inch long: When the Rod is of Braſs 3 Feet long, the Point *A* muſt be of Steel 1 Inch long, to prevent its wearing away, or loſing its Point; which conical Point is made to ſcrew on and off.

I had the firſt Rods made $1\frac{1}{2}$ Inch thick at *B*, and of the ſame Thickneſs 6 Inches up; but I found Inconveniences from that Form, and that a Rod all of a Size was better.

CD, *cd*, are two iron Supporters, joined by a flat croſs Bar at Bottom *Dd* two Inches long, in the middle of which is a Point $\frac{1}{8}$ Inch high under *B*, which goes into an Hole at the Bottom of the Rod *B*, and ſerves to keep the Rod in its Place at Bottom, as the croſs Bar ** having an Hole in it, thro' which the Rod paſſes, does in the middle or about $\frac{2}{3}$ up the Supporters, and the Point *A* goes into a ſmall Hole in the under Side of the Lever; all which keep the upright Rod firm and ſteady in its Place. The iron Supporters are flat, or parallel to the Front of the Machine from *C* to *X* and *c* to *x*, where they are twiſted half-round, ſo that the lower Parts *XD*, *xd* ſtand at right Angles with the upper Parts. This Contrivance gives the freer Acceſs to the Rod for the Sand or Fluid into which the Machine is ſet to meaſure the Heat of it, the Supporters ſtanding 2 Inches aſunder at *Dd*; and that the Degrees of Heat

may be compared uniformly in different Experiments, the Bottom of the Rod muſt always be immerſed to the ſame Height in the Matter to be examined; and therefore I make a Mark, a ſmall Furrow † quite round the Rod, $1\frac{1}{2}$ Inch from the Bottom *B*. For the deeper the Rod is immerſed into any Matter, it will be lengthen'd the more by the ſame Degree of Heat.

EF, the Lever, which turns upon an Axis *G*. At *F* is faſtened a String, which, paſſing twice round the ſmall Pulley *H*, has a Weight *I* hanging to the other End of it, of about half a Pound, being enough to keep the String always ſtretch'd. At the other End *E* of the Lever is hung another Weight *L*, which muſt be heavy enough not only to counterbalance the longer Arm *GF*, but preſs down upon the Point *A* with a Weight ſufficient to keep its ſteady.

MNO, is the back Part of the Plate, like the Dial-Plate of a Clock made of Braſs. See the Front of it at *Fig.* 3.

The Pulley *H* turns upon an Axis *C* in *Fig.* 3. which goes thro' the Plate, and on the other Side or Front of the Dial-Plate carries a Hand or Index *AB* in *Fig.* 3.

N. B. *G* being the *Fulcrum* of the Lever, the Diſtance *GA* being very ſmall, and the Diſtance *GF* being very great, the ſmalleſt Motion at *A* will produce a very great one at *F*, and therefore the Index will turn very ſenſibly upon the Plate.

The Proportions of the Rod and Lever are diſcretionary; my Rods both of Steel and Braſs are 3 Feet long in one ſolid Piece, but they have each a Point or Cone of Steel 1 Inch high, that ſcrews

upon the Top at *A*. The Lever has 4 Inches from *E* to *A*, $1\frac{1}{7}$ Inch from *A* to *G*, and 12 Inches from *G* to *F*; the Diſtance of *G* above *c* is $1\frac{1}{2}$ Inch, the braſs Pulley *H* is $\frac{1}{2}$ Inch Diameter; all the other Parts of the Machine are of Oak. The main Support or Pillar *PQ* is 1 Inch ſquare, $2\frac{1}{2}$ Feet high, and at Bottom is let thro' a Groove at *Q* made in a great heavy Block or Pedeſtal of Wood *RS*. In this Groove the Pillar may be raiſed higher or lower, in order to adjuſt the Height of the Pillar to the Situation, which the Bottom of the Rod *AB* may require in different Experiments; and it is to be fixed in that Place by a Screw at *T*, which goes thro' the Front of the Block, and preſſes againſt the Bottom of the Pillar.

Fig. 3. repreſents the *Dial-Plate*, or Front of the Plate mark'd *MNO*: In *Fig.* 2. it is a Plate of Braſs, with ſtrong Paper glued upon it, and may be of what Size you pleaſe; mine is 11 Inches over.

AB is the Hand or *Index*, which ſlips on very ſtiff upon the Axis *C*, that carries the Pulley *H* in *Fig.* 2. The outer Circle is to be left wide enough to contain the chemical Characters or Marks which are to be made upon it, the Arch *DE* contains the Diviſions of *Fahrenheit*'s Mercurial Thermometer; the Arc *FG* thoſe of *Reaumur*, or the Spirit of Wine Thermometer.

In order to adjuſt this Inſtrument for Uſe I place the Bottom of the Rod *B* in *Fig.* 2. immerſed up to the Mark † in cold River or Rain-Water, in a Veſſel proper to be ſet over the Fire; and when it has

has boiled for a Quarter of an Hour, I turn the Index *AB* in *Fig.* 3. till it ſtands in the horizontal Poſition, as at *B*, being the Point of boiling-hot Water, and which anſwers to Diviſion 212 on *Fahrenheit's* Arch. I then take it out of the Water, and dry it, by holding it a little over the Fire: And now great Care muſt be taken, that nothing alters the Situation of the Index upon the Axis; even a Nut to ſcrew on upon the Axis at *C* may be the beſt to keep it fixed. If the Inſtrument be left to cool in the Air, the Index will fall below *B*, ſhewing the Degrees of Cold, or leſs Heat than boiling Water; and if put into melting Tin, Lead, *&c.* it will ſhew the Degrees of Heat above boiling Water. A braſs Rod will ſerve for an Inſtrument to meaſure the greateſt Degrees of Cold, and all the Degrees of Heat, to the melting of Silver or Gold; but if you have a Mind to make one to meaſure greater Degrees of Heat, the Rod muſt be of Steel, or the fineſt Iron. A Rod of Braſs, according to Dr. *Muſchenbroek's* Experiments, *l. c.* was found to lengthen 377, when one of Iron lengthen'd only 230 Parts. An iron Rod, being regulated by boiling Water, as above directed, will meaſure not only the Heat of melted Tin and Lead, but of Silver, Gold, and Copper, and will even ſhew the Degree when Iron itſelf begins to melt, which will be the greateſt Degree of Elongation of the Rod juſt before the Bottom of it runs; and I imagine, that an Inſtrument may be conſtructed with Supporters, and a Rod made of Tobacco-pipe Clay, which, being regulated by boiling Mercury (for it muſt never touch Water), may

be adapted to meaſure ſtill greater Degrees of Heat, till the Materials themſelves melt into Glaſs.

I ſhould adviſe, that not only the Scale of this ſort of Thermometer, but likewiſe of all others, be determined by Experiments, without regarding any Equality as to Meaſure between the Diviſions, and that in every Individual that ſhall be made; for a Difference in the Length and Thickneſs of the Rods in this ſort will make a Difference in the Scale, as much or more than the Inequality in the Cavity of the Stem, or glaſs Tube of other Thermometers, which can never be juſt, if applied to a Scale whoſe Diviſions are made equal; unleſs the Cavity of the Stem be perfectly equal, which it is impoſſible for any Workman to undertake to do, and which is very ſeldom, if ever, hit on by chance. Therefore, in theſe Inſtruments, let the Point *B* in *Fig.* 3. or the horizontal Poſition of the Index, be the Situation of the Index when the Rod has ſtood a Quarter of an Hour in boiling Water; there mark ▽ *boiling* on the outer Circle; on *Fahrenheit's* Arch mark 212. then ſet your Machine up to the Mark + into melting Tin, which is the Metal that melts eaſieſt. When the Rod is arrived to its greateſt Elongation in that Metal, inſcribe the Character ♃ on the outer Circle; do the like with Lead, and ſet the Character ♄ at it. At the boiling of Mercury put the Mark ☿, and on *Fahrenheit's* Arch mark 600. the utmoſt Extent his Mercurial Inſtruments can meaſure: Then proceed to the melting of Silver, and ſet the Mark ☾; at the melting of Gold place the Mark ☉; at the melting of Copper place the Mark ♀; at the melting of Iron place the Mark ♂, the moſt difficult to melt of all Metals.

As

As the Diviſions pointed out by the Index will be different with Rods of different Metals or Subſtances, you may make different Circles upon the Plate for the Range of the different Rods, and mark them; the Iron Rod, the Braſs Rod, the Clay Rod; and ſet the ſeveral Marks above ſpecified upon each Circle apart; or you may, to avoid Confuſion, have a different Inſtrument for each kind of Rod.

Being obliged to take down my *Athanor* and Wind-Furnace, upon removing twice to different Houſes, and not having rebuilt them where I now live, I have not had Opportunities yet of fixing the Scale of my own Inſtrument, which was one Reaſon why I did not publiſh an Account of my Invention ſooner; for I hope hereafter to be able to compare the Degrees of Heat neceſſary for the melting of each Metal, and to determine the Queſtion whether Metals in the higheſt Degree of Fuſion are ſuſceptible of greater Degrees of Heat by increaſing the Fire, as Water thoroughly boiling can never be made hotter; nor did I intend to have publiſh'd any Deſcription of this Inſtrument till I had completed Tables of the Degrees of Cold and Heat, from *Fahrenheit*'s Experiment of Cold produced by Art 40 Degrees below 0 to the Heat of melting Iron.

According to *Fahrenheit*'s Scale, the Heat of the ſtrongeſt Sunſhine is at about 80. Spirit of Wine boils at 176. Water at 212. the *Lixivium* of Salt of Tartar at 240. Spirit of Nitre at 242. Oil of Vitriol at 546. Quickſilver at 600 *.

As

* *See* Auguſtin. Griſchow *Thermometria comparata accuratius, & Harmonica.* Berolini 1740. 4*to.* p. 10.

As all chemical Digeſtions, where an equable Heat is to be continued for ſome time together, will come in between hot Sunſhine and the boiling of Quickſilver, a Thermoſcope of that Range will be ſufficient for common Uſes; and therefore one fitted with a braſs Rod will anſwer theſe Purpoſes.

In large Furnaces for running down Ores, or melting great Quantities of Metal together, it is not poſſible to place ſuch an Inſtrument; but then in Lead and Tin there may be ſmall Outlets contrived, into which ſome of the melted Metal may be permitted to flow, and remain in Contact with the ſame Body of Metal within, where the Inſtrument may be placed; and for placing a Thermoſcope in Iron, Copper, or Glaſs Furnaces, there may be a Place contrived, which ſhall not open into the Furnace, but have the Thickneſs of a Stone or Brick left between, upon which the Inſtrument may be plac'd; and tho' in ſuch a Situation it will not meaſure the actual Heat within the Furnace, it will always give the relative or comparative Heat in the like Circumſtances at different Times, and ſo ſhew us how to regulate the Heat within.

Altho' a Chemiſt ſhall have one of theſe Inſtruments to meaſure the Heat, he ſhall have uſed in any Experiment, and have noted down the ſeveral Degrees made uſe of, and the Time each laſted, he ſtill labours under another Difficulty, which is the not being able to command any required Heat, and that it ſhall laſt a certain required Time, unleſs it be below that of boiling Water, which may be procured and continued by various Contrivances of Lamps, either of Spirits, or of Oil; but how to continue a Fire for 12 or 24 Hours together, without Attendance, which ſhall continually keep Quickſilver boiling,

boiling, Lead in Fuſion, or may be let down ſo low as not to exceed the Heat of Sunſhine, and then be raiſed again, and that without letting out the Fire, or moving the Veſſels, may ſeem almoſt impracticable; but by an Improvement of the Furnace the antient Chemiſts call'd their *Athanor*, I hope to ſucceed in it, which may be the Subject of another Paper.

The Rev. *Stephen Hales* D. D. that moſt worthy Member of the *Royal Society*, to whom the World is greatly indebted for many accurate Experiments, and uſeful Diſcoveries, upon hearing the Minutes of my Paper deliver'd in to the *Royal Society*, on *May* 8. 1735. read upon the *Thurſday* following, deſired me to lend him the Original for ſome Days, telling me he had ſome Thoughts of making a Thermoſcope with a Rod of Lead. After a few Days he returned me my Paper, with the following obliging Letter, and kind Remarks.

SIR,

I HAVE read over your *Thermometrical Tract* with Satisfaction, and believe it will be of good Uſe. The Want of aſcertaining the Degrees of Heat and Cold is a great and important *Deſideratum* in Experimental Philoſophy.

What I intended to do was only this, *viz.* to get a leaden Wire, of ſuch a Size and Strength as to bear its own Weight, to have it as long as the longeſt Gun-barrel I could procure, and to have it ſuſtain a Lever as you have done; then to pour boiling Water into the Barrel, for a long time, till the Lever

riſes

riſes no more; the Water to have Vent at the Bottom, yet ſo as to have the Gun-barrel always full of Water; the Breech-Pin to be out, and the leaden Rod to reſt on a Piece of Wood ſet upright, according to the Courſe of its Fibres, not ſideways.

To give at the ſame time to a Mercurial Thermometer the Heat of boiling Water.

Then to take the freezing Point of the Leaden and Mercurial Thermometers; and afterwards to graduate all the intermediate Degrees, from the Mercurial Thermometer upon the Leaden Thermometer, as they occur.

Thus a Standard Thermometer may be made to graduate others by; but I will not now ſet about it, ſince you have undertaken the Subject.

His *Remarks* on the foregoing Paper.

Page. 673. *Thermometers* muſt be of excellent Uſe in Garden-Stoves; but foreign Plants muſt not be kept in an equal Degree of Heat in Stoves, to that of their native Country; *viz.* becauſe they cannot bear as great a Heat in a confined cloſe Air, as in an open free Air. I have been told of Coffee-Trees being killed here in *England* by this Miſtake: Such Plants muſt doubtleſs be kept warm*, but not ſo warm as in their native Country.

P.

* I ſhould think it beſt to leſſen the Heat in Stoves towards the Night, and ſo to keep the Plants expoſed to leſs Degrees of Heat a-nights than a-days, nay to vary the Heat daily, or to endeavour by Art to procure different Degrees of Heat, agreeable to the natural Viciſſitudes of the Climate the Plants come from, having Regard both to the Seaſons of the Year, and the State of flowering or Fructification of the Plants; ſo that the beſt Way of ranging Plants in Green-houſes or Stoves is according to the Climates they come from; for which Mr. *Sheldrake*'s Tables above-mentioned, *p.* 674. muſt be of excellent Uſe. *C. M.*

P. 676. [*All ſolid Bodies are obſerved to contract with Cold.*] I have found that Wood does not contract or dilate lengthways with Heat or Cold. I am told that Mr. *George Graham* [is about making] this Experiment, as I am alſo, in order to regulate *Pendulums*.

P. 682. I fear that *Boerhaave*'s wet Linen, which is ſo thin, may begin to freeze before all the *Mercury* or Spirit of Wine in the Ball of the Thermometer has the ſame Degree of Cold: Tho' hanging there long before and after freezing will bring it pretty near.

P. 683. [*A Rod* of Iron 3 *Feet long will have about* $\frac{1}{4}$ *Inch Increaſe*] or $\frac{1}{144}^{th}$ Part.

IV. *A Continuation of a Paper concerning* Electricity, *by* William Watſon *F. R. S. printed in theſe* Tranſ. N. 477, Article I. *ending* p. 501.

Read Feb. 6. 1745-6.

AS Water is a Non-electric, and of conſequence a Conductor of Electricity, I had Reaſon to believe that Ice was endowed with the ſame Properties. Upon making the Experiment, I found my Conjectures not without Foundation; for, upon electrifying a Piece of Ice, wherever the Ice was touched by a Non electric, it flaſhed and ſnapped. A Piece of Ice alſo held in the Hand of an electrified Man, as in the before-mentioned Proceſſes, fired warm Spirit, chemical vegetable Oils, Camphor, and Gunpowder prepared as before. But here great Care muſt be taken, that,

Philos. Trans. N.° 484. TAB. II.

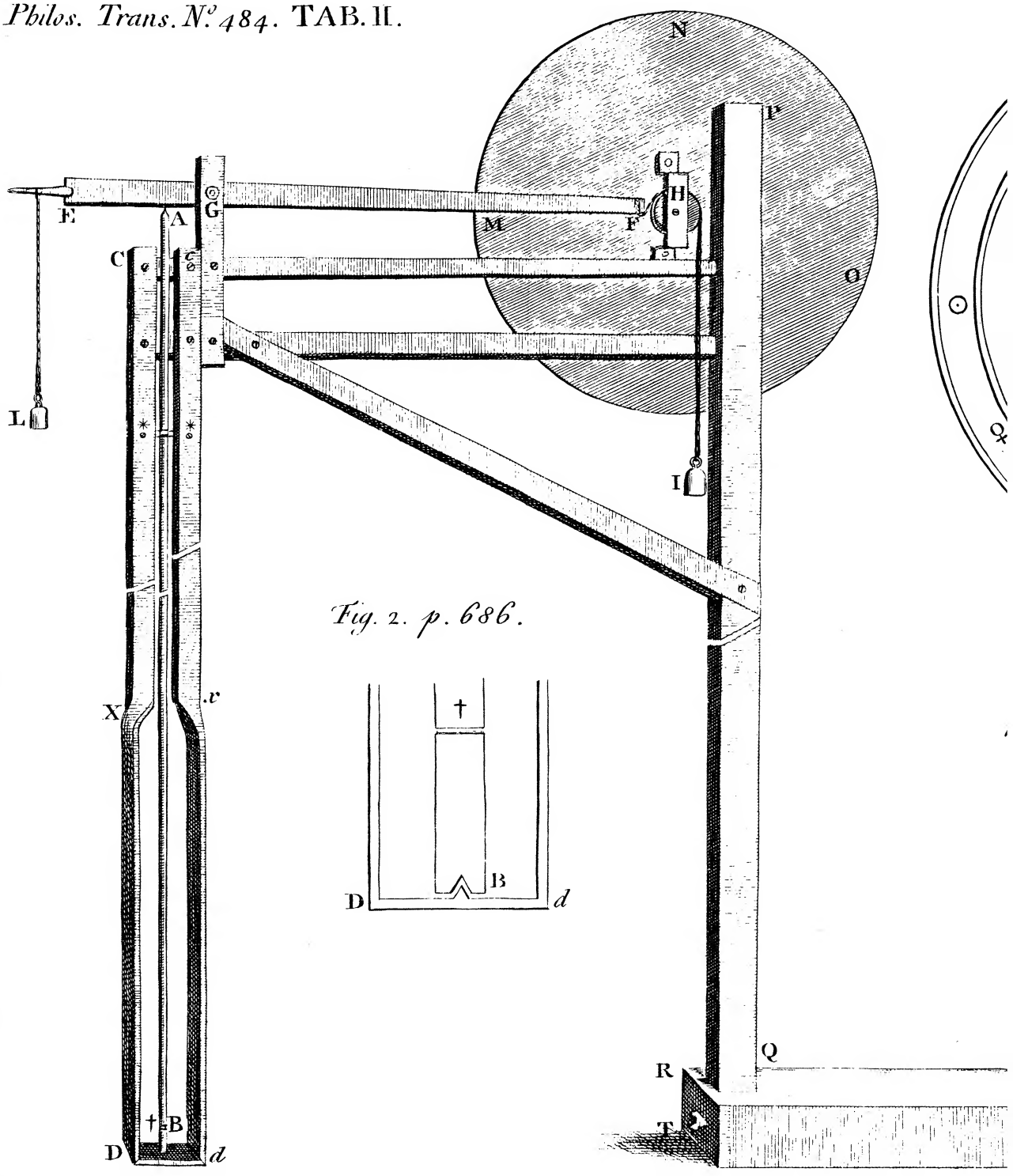


Fig. 2. p. 686.

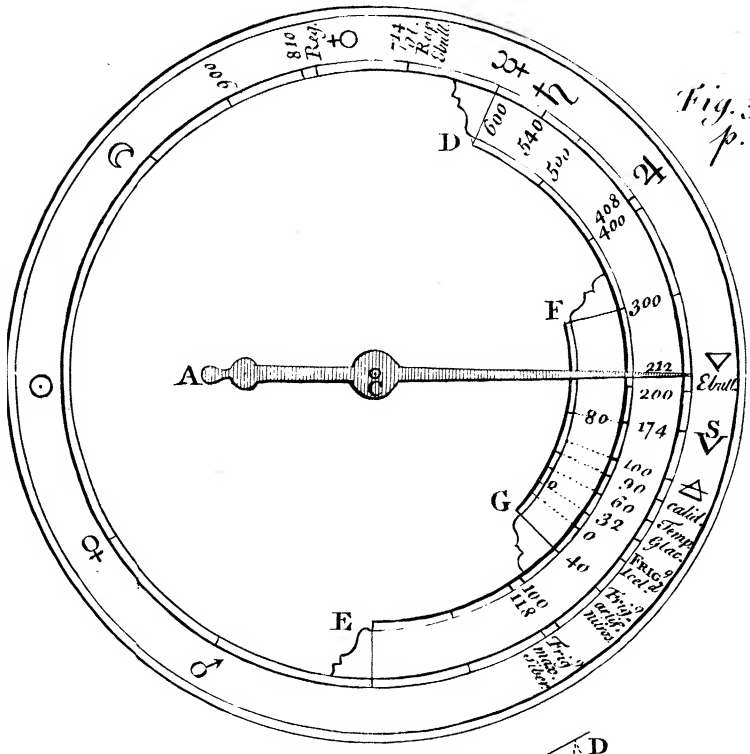


Fig. 3. p. 688.

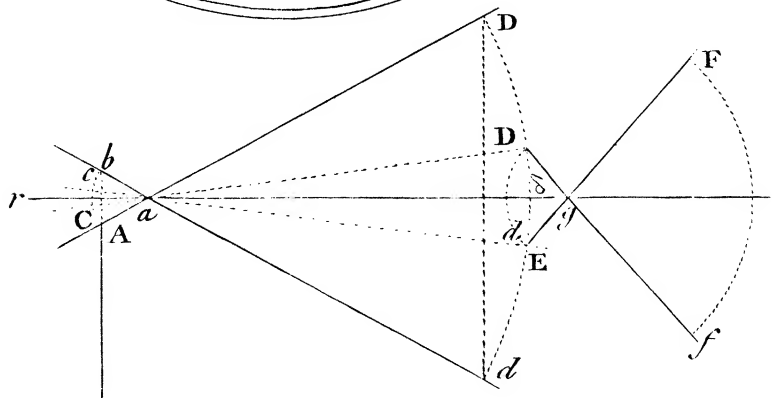


Fig. 1. p. 684.



C. Mortimer inven. & delin. J. Mynde sculps.

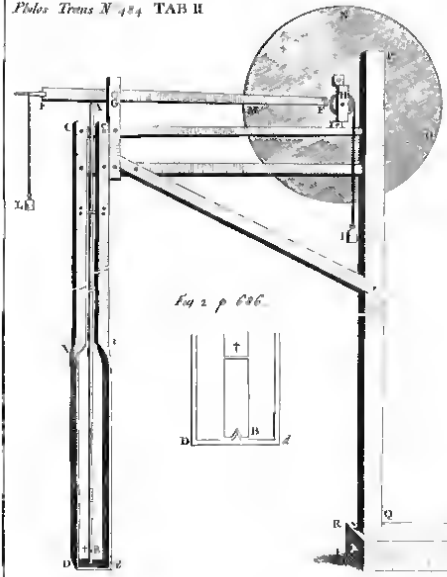


Fig 2 p 686

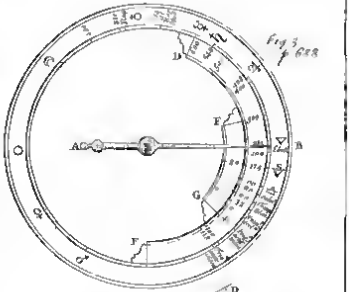


Fig 3 p 688

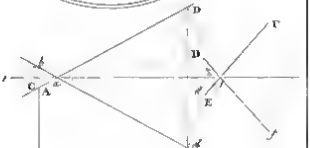


Fig 1 p 684

C. Mercator sculp. Edin. J. Wade sculp.